THE ANATOMY OF THE DIGESTIVE SYSTEM OF ONCOPELTUS FASCIATUS DALL. (HETEROPTERA: LYGAEIDAE)

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INTRODUCTION

Oncopeltus fasciatus Dallas occurs over a wide range extending from Massachusetts westward over the greater part of the United States east of the Rocky Mountains and south and westward to Florida, Texas, California, Mexico and Brazil.

Its principal host plant is the common milkweed *Asclepias syriaca* L. but late in the summer the insect may be observed on willow foliage and the flowers of golden-rod and other Compositae.

This study was initiated in a course in entomology at the Ohio State University given by Dr. C. H. Kennedy on "The Morphology and Development of Insects." The interest developed in this course led to further pursuance of the work as a thesis problem.

The insects studied were collected from foliage of the common milkweed growing in Vigo County, Indiana.

The writer wishes to express his sincere appreciation for the helpful criticisms and assistance given by Dr. Kennedy and also for the worthy suggestions of fellow students.

METHODS

The collected material was killed and immediately placed in Kahle's fluid where it remained for two hours. After washing the material was stored in seventy per cent alcohol. For much of the gross anatomy study live material was dissected under a normal saline solution. Mayer's Hemalum and Fast Green FCF were employed in staining histological structures.

GROSS ANATOMY OF THE DIGESTIVE TRACT

GENERAL ANATOMY

Upon the basis of embryological origin the digestive tract is divided into three major portions. The stomodaeum or fore-gut arises as an ectodermal invagination at the cephalic region of the embryo. In like

manner the proctodaeum or hind-gut arises at the caudal end. Since these two divisions of the tract are infolded portions of the body wall their own walls have the same essential structure as that of the body integument. The mesenteron or mid-gut is the connective portion of the tract between the stomodaeum and proctodaeum. Its epithelium is from embryonic endodermal tissue.

The three general divisions of the digestive tract are further differentiated into the following parts:

I Stomodaeum
- Pharynx
- Oesophagus
- Oesophageal valve

II Mesenteron
- First stomach
- Second stomach
- Third stomach
- Fourth stomach

III Proctodaeum
- Pylorus (?)
- Malpighian tubules
- Rectum
- Anus

In keeping with the phytophagous habits of the insect the entire digestive tract is of medium length being approximately one and one-half times the length of the body. It is relatively straight except in the regions of the second and third stomachs where it is coiled upon itself.

THE STOMODAEUM

The pharynx is a slightly enlarged portion of the stomodaeum just posterior to the mouth cavity and in the anterior half of the head cavity. It is a connecting portion between the mouth cavity and the oesophagus.

The oesophagus comprises the greater part of the stomodaeum and is approximately one-thirteenth the length of the whole tract. It is very narrow, tubular and extends dorsally from the pharynx along the median axis of the body. Its anterior half is enclosed by the head capsule while its posterior portion extends into the anterior part of the thoracic cavity joining the enlarged first stomach near the anterior edge of the scutellum. At the junction of the oesophagus and first stomach is located the oesophageal or stomodaeal valve.

THE MESENTERON

Just posterior to the oesophageal valve is the greatly enlarged first stomach. Its size and shape vary much depending upon the quantity of food material present within it but it usually extends well into the abdominal cavity along the median axis of the body. It is approximately one-third the length of the entire tract and is the region of the greatest diameter. Its walls at the anterior end usually lie in circular

folds while it enlarges in pear-shaped fashion posteriorly into a smooth-walled structure. In the thoracic cavity it is completely enclosed by thick bunches of wing and leg muscles.

THE SALIVARY GLANDS

The salivary or labial glands lie dorsally and closely to the anterior end of the first stomach in the thoracic cavity and extend anteriorly covering the posterior portion of the oesophagus. They are paired, one gland lying on either side of a median line through the walls of the oesophagus and first stomach. Each gland consists of four parts. Two parts are each single pyriform lobes. One part is bi-lobed. The other part is a convoluted tube the distal end of which lies within the head cavity.

Each gland has a straight-walled duct through which the gland empties into the mouth. This duct arises at the junction of the lobes of the gland; it has an open lumen. This exit duct and its mate from the other gland join at the base of the beak into a very short common salivary duct which empties into the hypopharynx. This region of the salivary pump was not investigated closely.

Plate I, Fig. 1 illustrates the right salivary gland slightly pulled away from the wall of the first stomach to show the distinct parts. The left gland is turned ventral side up to show the junction of the salivary duct and the gland.

According to Snodgrass these glands are of ectodermal derivation arising in the embryo as paired invaginations just behind the bases of the rudiments of the second maxillary appendages. They are therefore treated here in connection with the stomodaeum.

At its posterior extremity the first stomach gradually narrows into a convoluted tube called the second stomach. The walls of the second stomach lie in folds the entire length of that organ and are of a pale yellow coloration in living specimens. The diameter of the second stomach is usually about 0.5 millimeters although this may fluctuate somewhat largely due to the amount of food material contained therein. It is slightly longer than the first stomach being a little less than one-third the length of the whole tract. The second stomach is usually coiled within the middle third of the abdominal cavity, however, it may be found in the posterior third in those cases in which the first stomach is unusually enlarged with food material.

Figure 1 illustrates the second and third stomachs pulled out of their normally coiled position.

The third stomach is scarcely distinguishable from the second stomach when the third stomach is void of food material except for the lack of folds in its walls. When filled with food, however, it is usually oval to spherical in shape and of a dark brownish coloration. It is from two and one-half to three millimeters in length. The third stomach narrows down into a short, narrow, smooth-walled tube called the fourth stomach.

The fourth stomach is about one millimeter in length and terminates the mesenteron posteriorly, unless the next enlargement of the canal into which the Malpighian tubules enter may be of endodermal origin.

THE PYLORUS (?)

Connecting the fourth stomach to the rectum is a slightly flattened, bulbular, smooth-walled enlargement of the tract questionably called the "pylorus." It is approximately one millimeter in length. Its diameter is nearly twice its length. Histological study gives evidence that this region may be either part of the mesenteron or perhaps part of the proctodaeum. This evidence will be discussed in connection with the histology of the digestive tract.

THE PROCTODAEUM

As mentioned in the preceding paragraph the "pylorus" may be considered as the most anterior portion of the proctodaeum.

The Malpighian tubules are long and narrow blind tubes extensively coiled throughout the posterior half of the abdominal cavity lying particularly near the dorsal body wall. Their distal ends lie freely in the body cavity and their proximal ends join the "pylorus." They are four in number two of which independently enter each of the lateral walls of the "pylorus." Figure 1 illustrates these tubules as being broken a short distance from their origin. The Malpighian tubules are generally considered to be of ectodermal derivation.

Lying along the median axis of the body, posterior to and connected with the "pylorus," is a thin-walled, pyriform structure called the rectum. Its anterior end is enlarged being about one millimeter in diameter and two millimeters in length. Its walls taper posteriorly into a narrow tube which terminates at the anus.

HISTOLOGY OF THE DIGESTIVE TRACT

THE STOMODAEUM

The stomodaeum anterior to the posterior edge of the head capsule was not studied histologically.

The histological structure of the oesophagus is quite uniform except at its posterior end in the region of the oesophageal valve. A section through the oesophageal walls (Plate II, Fig. 2) discloses the following structures from within outward: (1) intima, (2) epithelial cells, (3) circular muscles and (4) longitudinal muscles.

An inner lining of non-cellular cuticula or intima lies apart from the epithelial cells and separates them from the lumen. The epithelial cell layer is very irregular in shape. It appears mostly as a homogeneous mass except for the scattered nuclei within it. No cell walls are noticeable. Both circular and longitudinal muscles are scattered and are from two to three strands in thickness.

At the junction of the oesophagus and first stomach is the oesophageal valve (Plate II, Fig. 4). The epithelial cells of the oseophagus are elongated forming a fold which extends partially into the lumen of the first stomach. There is a heavy grouping of circular muscles proximal to the basement membrane of the epithelial cells constituting the fold. It is particularly noted that there is no reversal in the relative position of the muscle layers at the oesophageal valve. The intima which lines the

oesphagus ends abruptly just posterior to the fold of cells which make up the valve indicating the posterior termination of the stomodaeum.

THE MESENTERON

Histologically the structure of the mesenteron is much the same throughout. It consists of a layer of epithelial cells resting upon a basement membrane, a layer of internal circular muscles and a layer of external longitudinal muscles. No peritrophic membrane is present which is considered quite typical of sap feeding insects. Likewise an intima is lacking. The epithelial cells throughout the mesenteron, unlike those in the oesophagus, are much larger and show distinct cell walls. A thinness of the muscular layers is characteristic of the mesenteron.

The wall of the first stomach is relatively thin in comparison with the diameter of the stomach. The epithelial cells are short but vary somewhat in shape from nearly cuboidal to oblong. Plate III, Figure 6 illustrates the cellular appearance of the first stomach when it is void of food material. The layer of circular muscles is particularly thin and consists of a single strand. The longitudinal muscles are few and very scattered.

In the second stomach (Plate III, Fig. 8) the epithelial cells are longer and more uniform in length. The circular muscle layer consists of one strand and a partial second strand. The longitudinal muscles, as in the first stomach, are few and scattered.

The histological structure of the third and fourth stomachs (Plate III, Figures 9 and 7) is particularly similar. The epithelial cells vary greatly in size, some cells being six times larger than other cells, thus making the epithelium very irregular in thickness. Activity of the digestive epithelium is noted particularly in the third stomach. Some of the distended epithelial cells in the third stomach are seen undergoing a degeneration process. Also, a regenerative cell is shown. In the degeneration process, according to Snodgrass, the mesal border of the degenerating cell swells out in the form of a bud, which becomes constricted at its base and finally separates as a free sphere from the body of the cell as illustrated on Plate III, Figure 9. These disintegrated cells are replaced with new cells formed from the regenerative cells. In the fourth stomach some of the epithelial cells show striated borders. The muscularis in the third and fourth stomachs is heavier than in any other portion of the mesenteron. A layer of two strands of circular muscles is present. No longitudinal muscles were detected in the third stomach. A few scattered longitudinals are noticeable in the fourth stomach.

THE PYLORUS (?)

This enlargement of the digestive tract, into which the Malpighian tubules empty, is made up of long, very thin epithelial cells resting upon a basement membrane. Lying closely to and outside of the basement membrane is a layer of rather heavy, plainly striated, longitudinal muscles from one to two strands in thickness. No circular muscles were detected. No pyloric valve was found. Because only longitudinal muscles are present there is no reversal of the muscular layers in the "pyloric" region.

The point of attachment of the Malpighian tubules commonly marks the anterior extremity of the proctodaeum. Embryologists also generally agree that these tubes take their origin as outgrowths of the proctodaeum. The fact that the Malpighian tubules enter the "pylorus" would indicate that this region is part of the proctodaeum. The proctodaeum, however, is characterized by having an intima. Contrary to this, the so-called "pylorus" has no cuticular lining. This condition, then, would indicate that the "pylorus" is a continuation of the mesenteron.

Snodgrass defines the pylorus as "an anterior part of the proctodaeum usually containing the pyloric valve, sometimes distinctly differentiated from the true intestinal region and forming anatomically the rear end of the stomach."

Our evidence, then, is not decisive as to whether the lining epithelium is derived from endoderm or from proctodaeal ectoderm.

THE PROCTODAEUM

The Malpighian tubules join directly into the walls of the "pylorus." The structure of these tubes is relatively simple. The lumen of the tube in cross section is enclosed by three or four large, thin-walled cells which contain very large and distinct nuclei. No muscularis could be detected.

The structure of the rectum is quite similar to that of the oesophagus. From its lumen outward it is made up of the following structures: (1) intima, (2) epithelial cells, (3) internal circular muscles and (4) external longitudinal muscles. The intima which separates the epithelium from the lumen lies more closely associated with the epithelial cells than it did in the oesophagus. The epithelial cells are similar to those in the oesophagus in that they show scattered nuclei and no cell walls. They are also very irregular in shape. The circular muscle layer consists of a single strand of muscles. The longitudinal muscles are rather heavy. They occur in scattered patches of from one to two strands in thickness.

Investigation of an anal sphincter could not be carried on satisfactorily due to the chitinized walls about the anal opening.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Gross dissection; alimentary tract removed in part from the body cavity. Left salivary gland turned ventral side up. Malpighian tubules cut off near their point of origin.

PLATE II

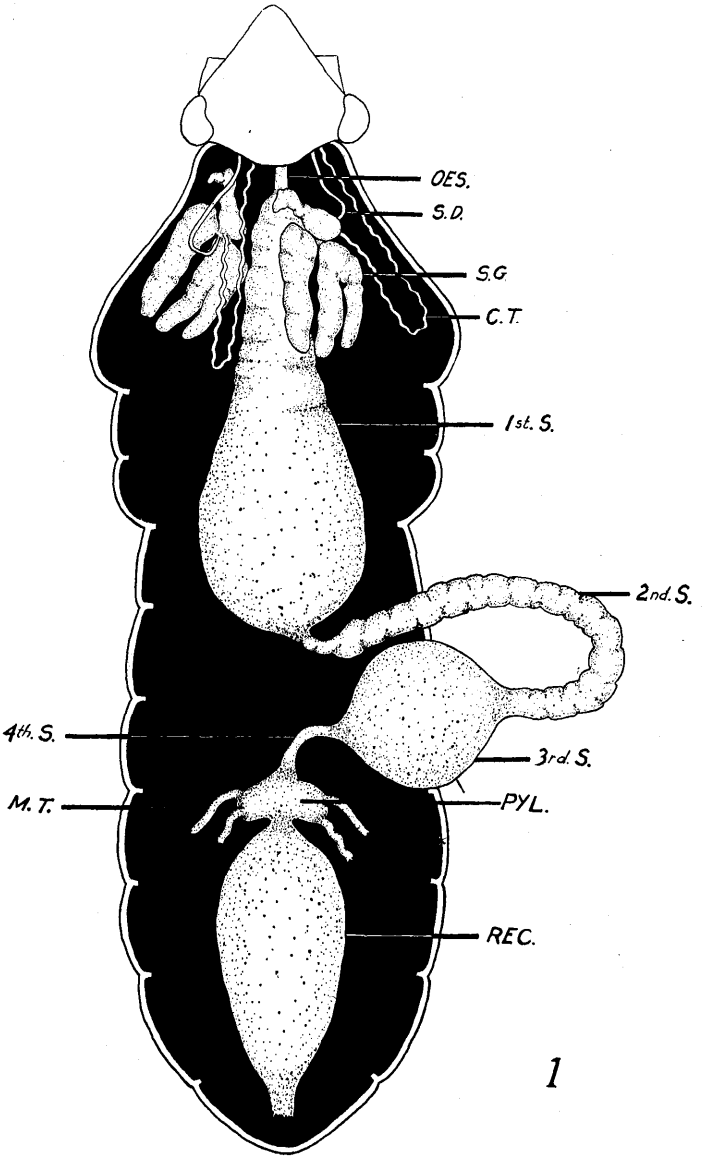
Fig. 2. Cross-section through the oesophagus.
Fig. 3. Longitudinal section through the "pylorus."
Fig. 4. Longitudinal section through a portion of the oesophagus, the oesophageal valve and part of the first stomach.
Fig. 5. Cross-section through a Malpighian tubule.

PLATE III

Fig. 6. Cross-section through the first stomach.
Fig. 7. Cross-section through the fourth stomach.
Fig. 8. Cross-section through the second stomach.
Fig. 9. Cross-section through the third stomach.

KEY TO ABBREVIATIONS

C.M.—Circular muscle.
C.T.—Convoluted tube.
EPI.—Epithelial cell.
INT.—Intima.
L.M.—Longitudinal muscle.
LU.—Lumen.
M.T.—Malpighian tubule.
OES.—Oesophagus.
O.V.—Oesophageal valve.
PYL. (?)—"Pylorus."
REC.—Rectum.
R.C.—Regenerative cell.
1st. S.—First stomach.
2nd. S.—Second stomach.
3rd. S.—Third stomach.
4th. S.—Fourth stomach.
S.B.—Striated border.
S.C.—Secreting cell.
S.D.—Salivary duct.
S.G.—Salivary gland.


OES.
S.D.
S.G
C.T.
1st. S.
2nd. S.
4th. S.
3rd. S.
M.T.
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REC.
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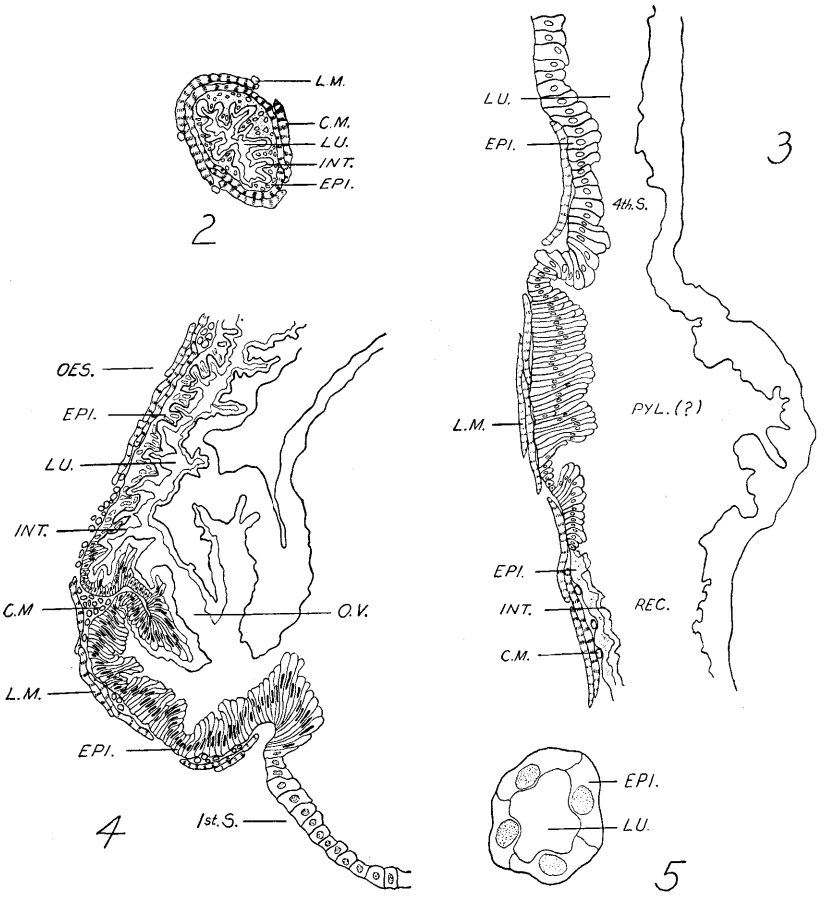
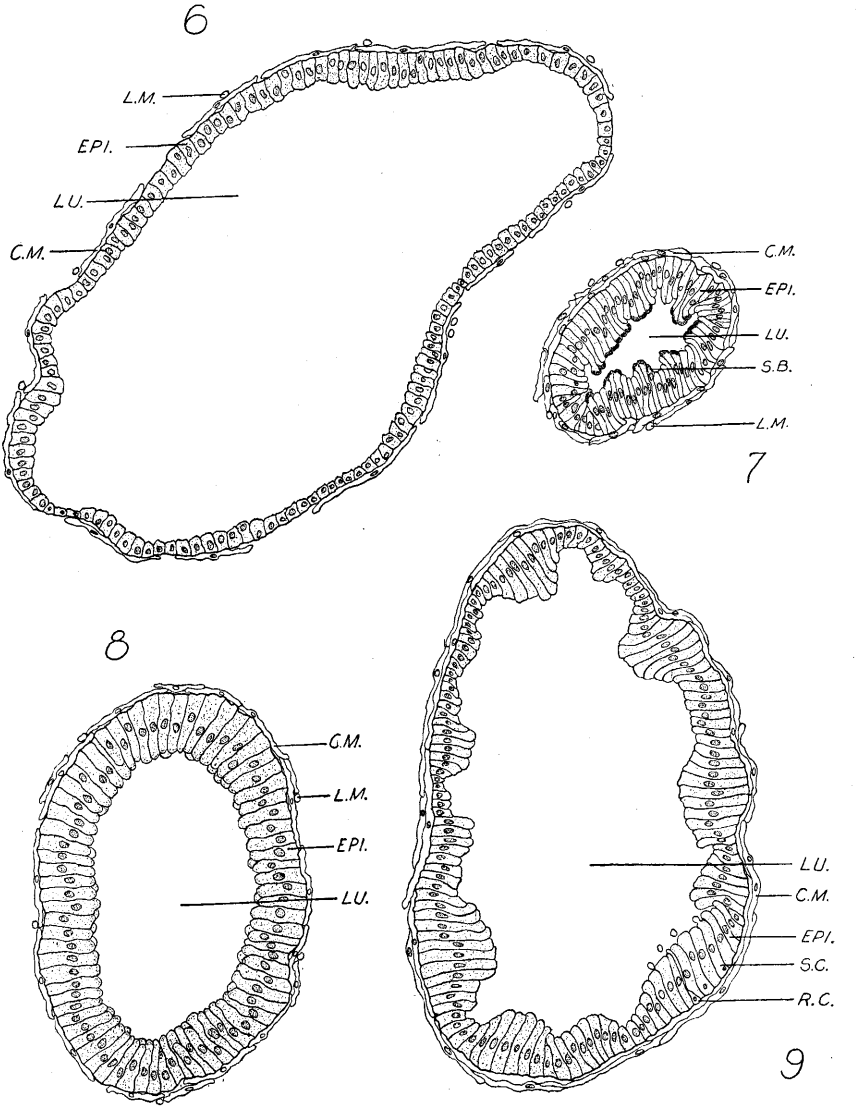
Oncopeltus fasciatus Dall.
Charles W. Hood

PLATE II

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L.M.
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